PCT/AU2004/001739

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Simple Title

A control device 4.

Detailed Title

Machine control device using information from light sensors.

Initial scope of this provisional patent

This provisional patent covers an invention that may be used in other situations and for uses other than press brake control however its initial design and marketing is for press brakes where productivity and/or safety are improved by safely and automatically driving the blade to a position ready for bending material placed onto the anvil.

Overview

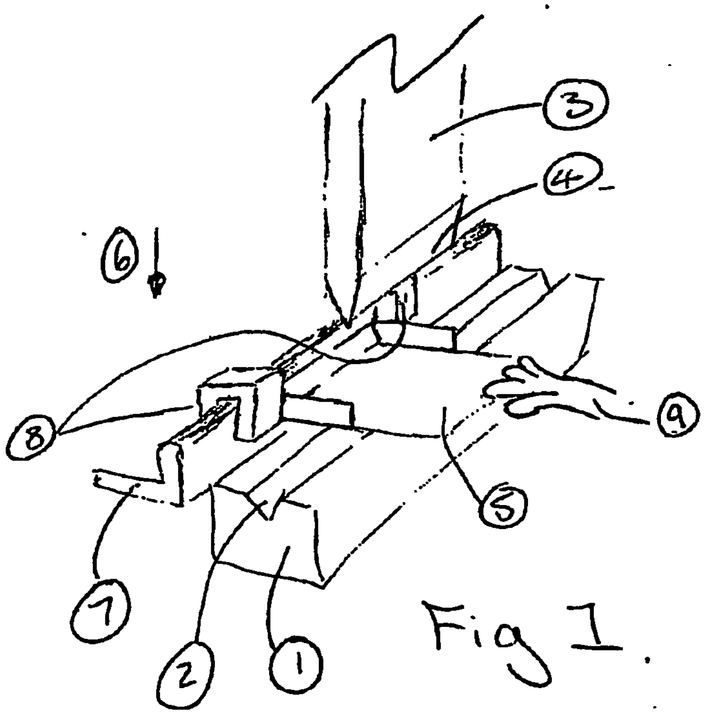


Fig 1.

A typical break press has a long anvil (fig 1/1) with a VEE (fig 1/2) along the top and a blade (fig 1/3) with a leading bottom edge (fig 1/4) that fits into the VEE of the anvil. To bend a piece of sheet metal (fig 1/5), most machines drive a back-gage (fig 1/7) into a position to align the material, the material may be slotted into a guide provided by the back-gage clamps (fig 1/8). The operator then activates the break press, driving the blade down (fig 1/6) so it comes into contact with, and then bends the sheet metal that has been placed onto the VEE of the anvil.

After the bend and if the blade has not been set to retract far enough then the material can be difficult to remove from the anvil or requiring the operator to unnecessarily use the retract switch.

For this reason, a press brake blade is often configured to retract to a height where the bent material can easily be removed, and a new piece placed onto the anvil to be bent.

This opening of the blade to a set height reduces productivity as the operator must wait for the blade to first retract and then approach the next piece of material.

The large opening increases danger to the operator as there is a larger gap for the operator to put fingers & hands into. Techniques such as having a programmable blade opening height for each stage of the bending process and/or a very fast approach speeds to the material (with lasers projected along the underside of the blade for safety) have been used to improve productivity.

To improve safety, the blade may be stopped a preset distance (often called the mute – or pinch point) above the material and the approach switch required to be released and re-asserted again before the bending action starts. This action reduces productivity as extra time is spent:
1) While the operator aligns the material and then activates the approach switch.
2) While the blade approaches the material.
3) While the operator waits for the blade to stop at the mute point and to release and reassert the approach switch.

These extra stops can lead to new dangers as the operator may get used to activating the approach switch unnecessarily, instead of just activating the approach switch to confirm the zone is safe and/or the material is aligned correctly.
Laser beams projected along the underside of a blade can be used to ensure fingers are not placed on top of material and improve productivity by permitting the blade to travel straight through the mute point in relative safety. This method still leaves the operator at risk of entrapment (tips of fingers trapped between the bending metal and the blade) while a method to reduce the possibility of entrapment is described in PCT/AU03/00707.

When bending a box, an operator may bend the two sides of the box then rotate the work piece 90 deg to bend the back of the box.

By one method, the operator aligns the material into a guide provided by the back-gage so the blade passes between the two sides in safety. Alternatively, the operator drives the blade to just above the material, aligns the material with the blade and then approaches the material again. By a third method, the operator drives the blade to be lower than the side up-stands of the material and then slots the material around the blade.

By the first and second methods, if the material isn't aligned correctly then the left or right edge of the blade can be broken, or the material crumpled due to the blade coming into contact with one of the up-stands. This would be likely to occur if the material is not seated properly into the back-gage guides when the approach switch is activated or if the material is not aligned correctly below the blade when the blade is re-activated.

The press bakes may also be fitted with a laser safety system adjusted to make the blade stop just above the up-stands or configures with a stop point, permitting the operator to ensure the material is positioned correctly for the blade to pass between the sides without coming into contact with them.
Due to the potential damage that can occur, operators often take extra care while performing these bends with productivity being reduced accordingly.
In another attempt to improve productivity, many presses are fitted with an auto-retract function. This

is often achieved by waiting until the blade reaches its bottom of stroke and then automatically retracting the blade while the operator still has the approach switch activated.

Operators may also inadvertently place the material to be bent onto the bed oriented the wrong way leading to the wrong side of the material being bent.

Some or all of these techniques are limited in some way as they do not entirely solve the problem of productivity being reduced through either the blade opening being unnecessarily large or the blade being stopped at top dead center or other places waiting for the operator to re-activate the approach switch. Some or all of these techniques may also result in unnecessary time being spent configuring the machine and/or unnecessary danger to the operator from large openings or potential damage to the machine or material.

The present invention seeks to at least in part to solve some or all of the problems described above.

The Invention

The contents of patent PCT/AU03/00707 are incorporated here by reference

The preferred embodiment for the new invention consists of the following:

Obstruction (blade/material and anvil) Sensing means:

SIDE VIEW.

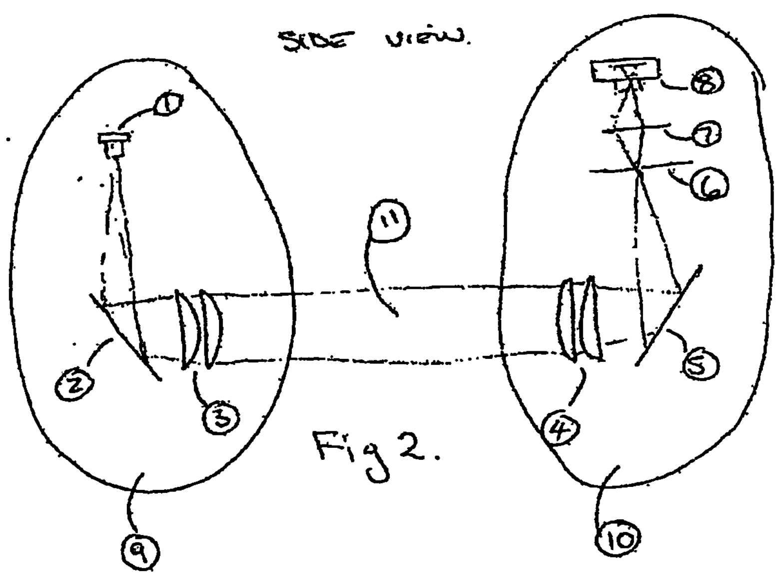


Fig 2.

A large area parallel ray light emitting means (fig 2/9) is used to illuminate the control zone (fig 2/11) so that objects illuminated by the light emitting means cast a shadow. The position, speed and shape of shadows are detected by a light receiving means (fig 2/10). A control means (not shown) analyses the information from the light receiving means and controls the machine accordingly.

The light emitting means (fig 2/9) consists of a laser diode (fig 2/1) that projects its diverging laser beam onto a mirror (fig 2/2). The mirror allows a long focal length to be used without making the device overly long.
Light from the mirror is columnated by the lens arrangement (fig 2/3) that may consist of aspheric, dual plano (flat on the back) convex lenses or other suitable converging lenses. The columnated light consists of substantially parallel rays of light projected over a large area.

The light receiving means (fig 2/10) consists of a lens arrangement (fig 2/4) to converge the large area light beam and a mirror (fig 2/5). The converged light is passed through a pin hole (fig 2/6) and onto a projection screen (fig 2/7).
Light hitting the projection screen creates and images that is detected in real time by a CCD camera (fig 2/8) and communicated to a control means (not shown).

Unlike the safety device described in patent PCT/AU03/00707, it may be necessary to keep the laser more precisely aligned with the receiver in order to accurately analyse obstructions in the control zone (fig 2/11).

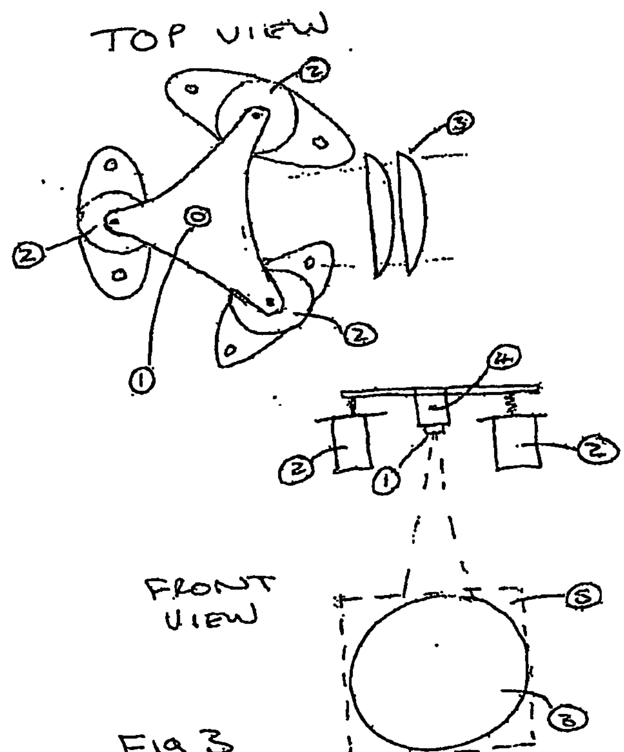


Fig 3

The preferred embodiment for aligning the laser beam has a vernier adjustment to automatically alter the direction of the columnated laser beam. This is achieved by moving the laser diode (fig 3/1) relative to the lens arrangement (fig 3/3) using three linear actuators (fig 3/2).

Moving the laser diode (fig 3/1) towards or away from the mirror (fig 3/5) so the optical distance to the lens arrangement (fig 3/3) decreases or increases causes the columnated laser beam to diverge or converge accordingly. The laser is moved laterally by mounting the laser below the fulcrum as shown in (fig 3/4). Moving the laser diode laterally relative to the lens arrangement alters the direction of the columnated beam without appreciably altering the quality of the columnated beam.

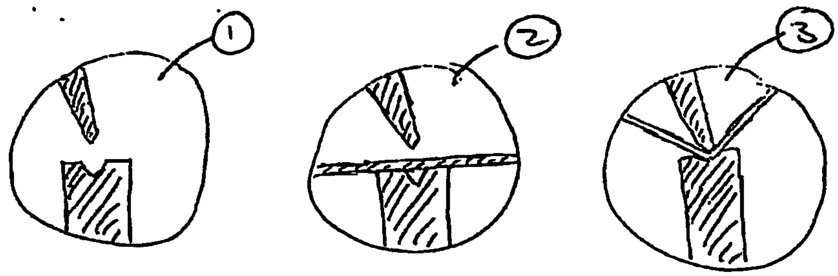


Fig 4

Fig 4 shows various images that could be analyzed by the control means, these images may be:

- a blade and anvil with no material on the anvil (fig 4/1)
- a blade and anvil with material on the anvil (fig 4/2)
- a piece of material bent by the blade and anvil (fig 4/3)

Alternative embodiments for the obstruction sensing means could include multiple flat beam lasers (fig 5/2) as describe in WO03/080268 or multiple spot lasers (fig 5/1) positioned to achieve a similar outcome.

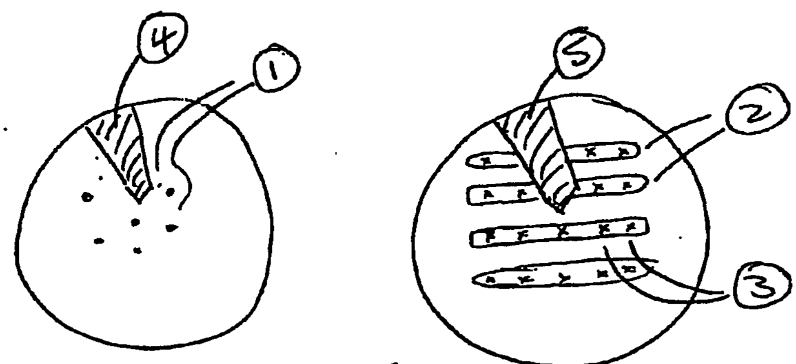


Fig 5

If many horizontal sensors (fig 5/3) are used (5 are shown here) then they can be used to determine the height that any obstructions occur at. To do this the blade position should be know at any moment and this information used to determine the height that a sensor is at when it becomes obstructed.

Material position sensing means:

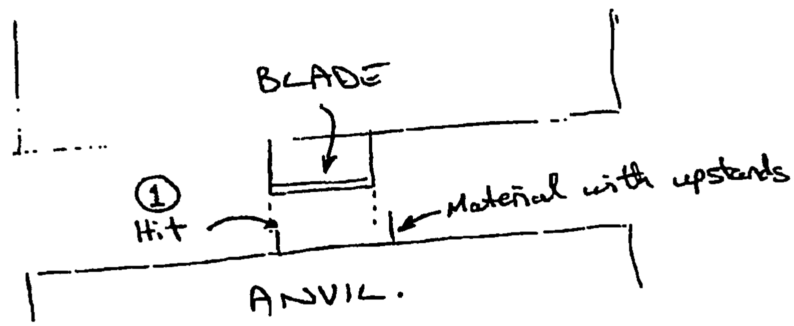


Fig 6

The image sensing means permits the control means to establish when a new piece of material has been placed onto the anvil and aligned front-to-back correctly, and also for the operator to work in safety as per PCT/AU03/00707. However, it does not permit the control means to establish if the material has been placed correctly laterally. Fig 6/1 shows a piece of material aligned incorrectly so that its up-stand will be hit by the blade. Material is not usually hit by a blade as a good operator takes the necessary precautions to ensure it doesn't happen.

One preferred embodiment for this invention includes a positive positioning or sensing means that can help ensure the material is horizontally positioned correctly.

The preferred positive positioning means requires the back-gage to have adjustable clamps as represented in Fig 1/8. As can be seen, the material can only be aligned when slotted between the two clamps of the back-gage.

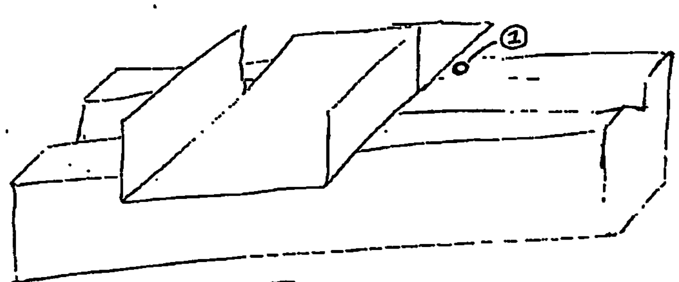


Fig 7

Fig 7/1 shows an inductive sensor mounted into an anvil with the material a little to the left, this would result in a low inductance from the inductive sensor. As the material position is varied from left to right, more of the sensor is covered. This results in the inductance to increase and/or the eddy current losses to increase accordingly.

The preferred material position sensing means has one or more inductive sensors mounted adjacent to, or into the anvil. By measuring the inductance of these sensors, the control means determines the relative horizontal position that the material has been placed into. As the material would be placed against a side stop, the material should be positioned correctly and the inductive sensor would be used

to confirm the position. Alternatively the inductive sensor or micro-switches could be mounted onto the alignment fingers of the back-gage to indicate to the control means that the material is positioned ready for the bend.

Control means:

The processing and control means (not shown) consists of a programmable device (say a DSP / microprocessor or computer) that analyzes information from the light receiving means and controls the machine accordingly.

The control means uses the shadow maps and shadow mask expansion techniques that are described in PCT/AU03/00707 and also retains some or all of the safety techniques described in that PCT.

The control means also has a blade position sensor that permits the control means to know the position of the blade relative to the anvil. Alternatively, the control means can estimate the position of the blade relative to the anvil by observing the movement of obstructions (images of material and anvil) relative to the blade.

The control means may also have a material position detector or positive guide to ensure the material is aligned correctly.

Preferred Operating Embodiments:

Three preferred operating embodiments are described, each with advantages suited to particular production tasks or machine types. An overall preferred embodiment is envisaged that either operates similarly to one of these, with a combination of all three modes, or has a means for switching between these modes.

For embodiments one and three (flow diagrams 1A, 1B & 3), the operator keeps the approach switch active after the material has been bent, this allows the blade to follow the material.

For embodiment two (flow diagram #2), the operator selects a 'follow the material' mode using a selector switch. In 'follow the material' mode, the control means follows the material after the approach switch has been released (for safety reasons – say if the operator goes off to morning tea – the material is only followed for say 1 minute after the approach switch has been removed). The blade only follows the material while there is no obstruction around the blade so the control means can ensure the is not going to come into contact with anything.

For all three embodiments, after bending a piece of material, the operator keeps the approach switch asserted while the processing and control means retracts the blade from the material allowing the material to be removed. The operator then puts the next piece of material onto the anvil while the processing and control means keeps the blade clear and then drives the blade so it descends to just above the material ready for the next bend.

Using the light emitting and receiving means described in PCT/AU03/00707, a potential problem exists where an up-stand on the material being bent obstructs the light beam casting a shadow that the blade will overlap. In this situation, the processing and control means cannot determine if the material is positioned correctly and so, slows or stops the blade. A few ways to allow the blade to descend below the height of material up-stands (see fig 10/2) are envisaged:

- The operator releases and asserts the approach switch confirming it is safe to continue (this is shown in all flow diagrams).
- The operator places the material onto the anvil, but slides the material to a position that does not create a shadow that overlaps blade. This assures safety allowing the blade to descend to just above the flat part of the material. Once the blade has descended and stopped, the operator slides the material into position ready for bending causing the shadow of the material to overlap the shadow of the blade (this is allowed for in all flow diagrams).
- The blade stops when an obstruction is detected below the blade, but is permitted to travel if the shadow of the material matches a shadow in the shadow stack even if the shadow of the material overlaps the shadow of the blade. The permitted speed would be determined by the degree of overlap and the position and shape of the obstruction relative to the appropriate image stored in the shadow stack (this is similar to the previous point but allows the operator to slide the material into position before the blade has fully descended).
- The blade is slowed while traveling through the location where the shadow of the blade overlaps the shadow of the material (this would help the operator align the material).
- Either a horizontal position sensor (as shown by the ' * ' of flow diagram #1) or guides (as described above) are used. This gives visual or analogue feedback to the processing and control means confirming the material is positioned correctly.

It is noted that using some of these modes, damage to the material and a danger to the operator can result if the material is not aligned correctly therefore heuristics would be programmed into the processing and control means to optimize productivity while minimizing the risk of damage to material or danger to the operator.

An automatic mode is also shown in dotted lines where for certain bend types, the operator need never release the approach switch. In this mode, after bending a piece of material, the operator removes the material and places the next piece of material ready to be bent. The processing and control means bends the piece of material after confirming it has not moved for a pre-determined period and that it is safe to perform the bend. To reduce the chance of material misalignment, for preferred embodiments #1 and #2, the processing and control means doesn't start the bend unless the image of material and anvil matches one of the images in the shadow stack.

The first embodiment is most suited for presses where smooth operation of the blade is possible, of the three embodiments this one results in the greatest blade movement but has the advantage that it also gives the greatest productivity (due to good clearance under the blade) while giving the operator continuous control over the blade movement. Also the operator is provided with visual feedback, confirming the material is aligned correctly.

Shadow Stack:
A shadow stack is used for embodiments #1 and #2. Once an initial bend has been completed, the image, the material position and shape immediately prior to the material being bent is stored into the shadow stack. On subsequent bends, the control means compares the received image against the images stored in shadow stack and only permits the blade to come close to the material if they match. The first embodiment, provides visual feedback to the operator (indicating when the material shape is recognized) keeping the blade a preset distance from the material until the received image matches and image in the shadow stack the blade is then lowered to just above the material indicating the material shape has been has a recognized.

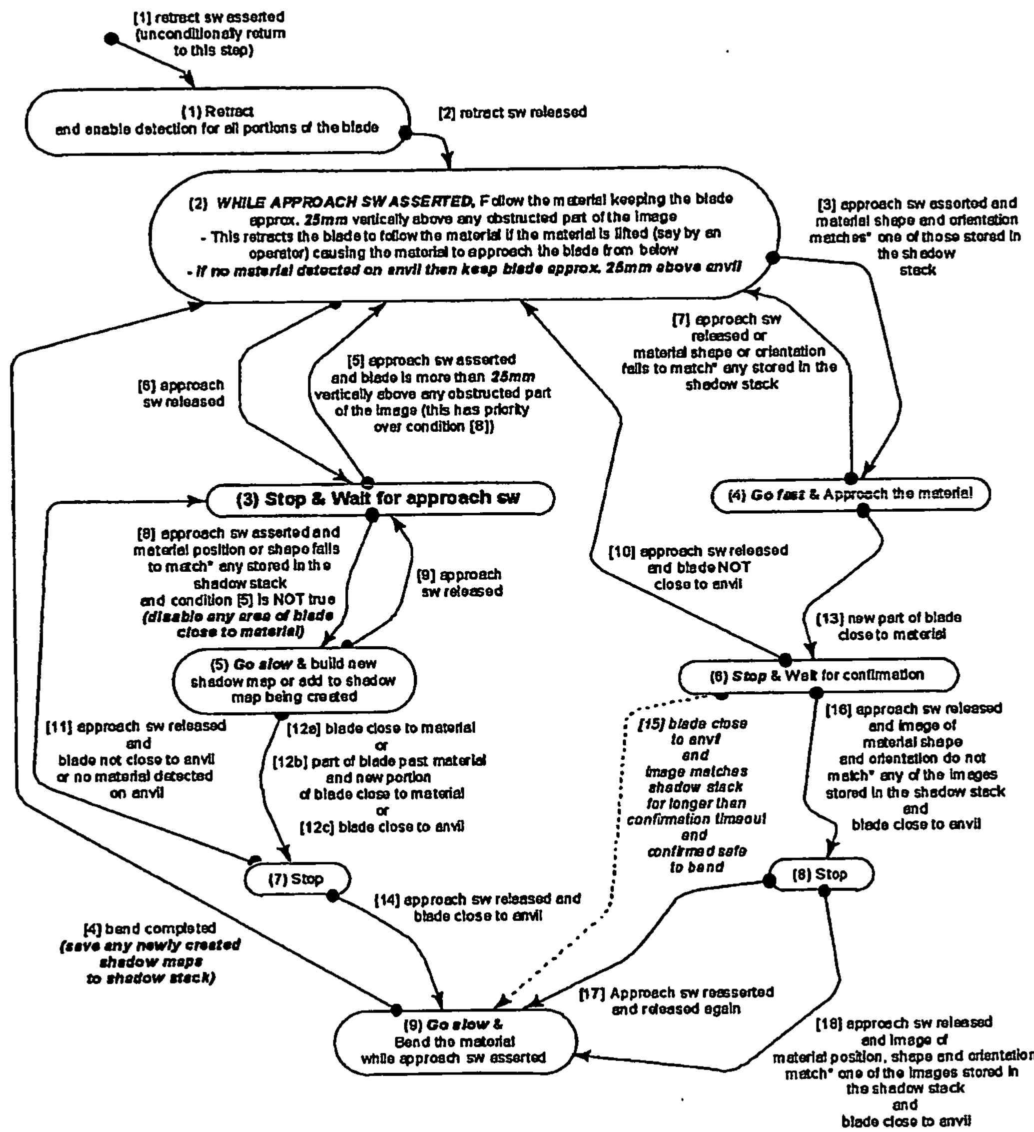
The second embodiment operates similarly to the first, however, the approach switch doesn't have to be held to permit the blade to follow the material. This allows the operator to move around, leaving the approach switch for short periods. Safety is maintained as the blade doesn't move unless either the approach switch is asserted or unless there is no obstruction around the blade.

This embodiment would be useful in situations where it is hard to keep the approach switch asserted while placing and removing material from the anvil.

For embodiments #1 and #2, the operator has the maximum opportunity to ensure the material is aligned correctly. If either the material position or shape are not recognized in the shadow stack then these embodiments insert and extra stop before bending the material (refer to flow diag 1A, 1B & 2).

No Shadow Stack:
The third embodiment provides the most consistent operation while still maintaining good productivity, this operates similar to embodiments #1 while the operator creates an image to be stored into the shadow stack. This is the most intuitive mode, requiring less training for operators.

Preferred Control Embodiment #1:



* NOTE1: If an inductive material position sensing means is used then the inductance of the sensor is measured and stored with images when they are stored into the shadow stack When images are compared with the shadow stack, the inductance of the sensor is also compared against the stored value
\# NOTE2: Text in BOLD / ITALICS are given for indication only as situations exist where these may not be entirely appropriate

Flow Diagram 1A Follow Material while Approach Asserted

An overview of the control means operation is shown in flow diagram 1A. States are numbered in the curved brackets, and conditions required to progress from state to state are shown in the square brackets.

To describe the operation of the control means for this embodiment, the bending of a simple box is described here.

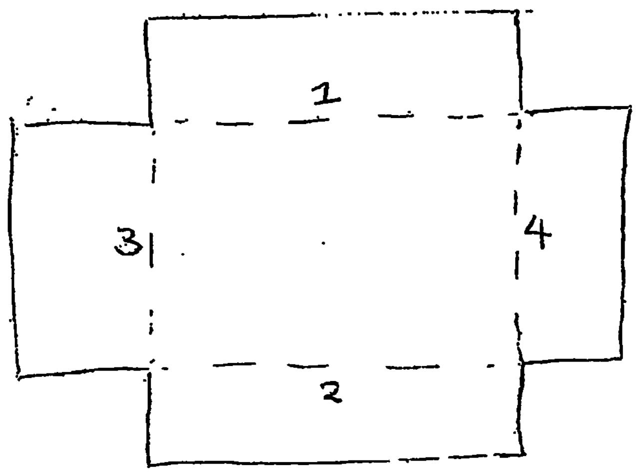


Fig 8

Referring to Fig 8, the shape of the material being bent is shown.

The operator may activate the retract switch fulfilling condition [1] forcing the control means to enter state (1) and retract the blade. The blade may be opened further than usual by using the retract switch. When the operator releases the retract switch the control means progresses to state (2).

Bending Side #1

The operator programs the required position of the back-gage for the first bend (fig 8/1) and asserts the approach switch. As the control means is in state (2) and the approach switch is asserted, the control means drives the blade to *(the position shown in fig 9/2)* where the anvil fills the lower 20% (say 25mm below the blade) of the image area.

The operator places the material onto the anvil causing the blade to raise and then lower to stop higher by the thickness of the material. The blade comes to rest with the lower 20% if the image area obscured by the material *(as shown in fig 9/3)*.

The operator releases and reasserts the approach switch fulfilling condition [6] and then condition [8] so the control means progresses through state (3) to state (5). In state (5) the control means drives the blade slowly to the bed creating a shadow map *(as shown in fig 9/1)* until the blade is close to the anvil *(as shown in fig 9/4)* fulfilling condition [12c] and putting the control means into state (7).

The blade stops in state (7) so the operator releases and re-asserts the approach switch fulfilling conditions [14] so that the control means passes on to state (9).

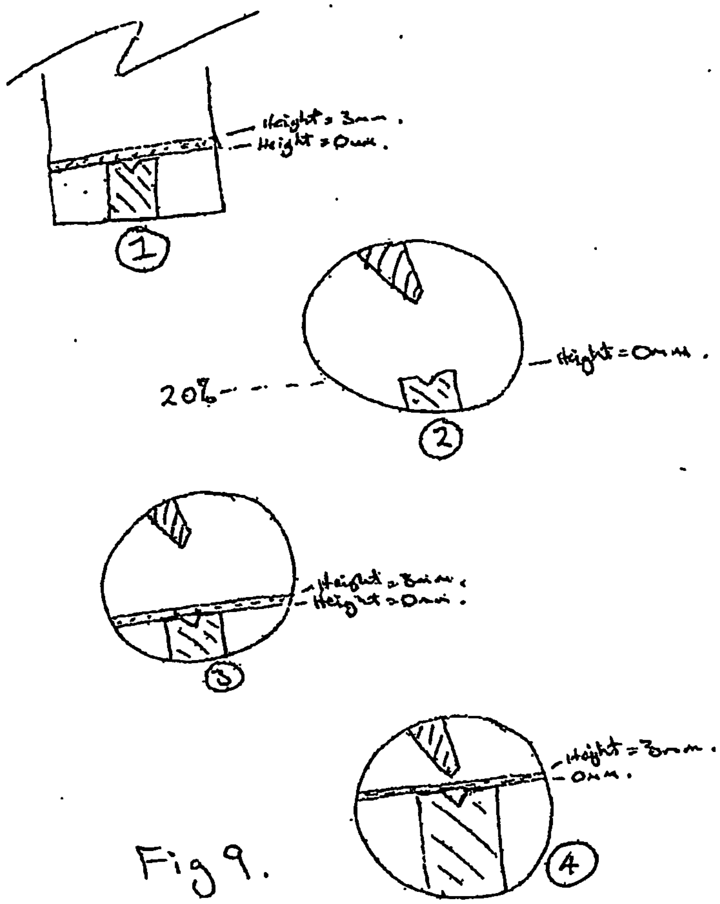


Fig 9.

In state (9) the material is bent until condition [4] is met and the control means returns to state (2) saving the newly constructed shadow map to the shadow stack.

Bending Side #2

In state (2) the blade retracts until the image of the bent material fills only the lower 20% of the image. The operator, keeping the approach switch asserted, removes the material and rotates it through 180 deg to bend the other side of the material as per fig 8/2.

The blade approaches the material meeting conditions [3] and [13] passing through state (4) to state (6).

The blade stops in state (6) so the operator releases and re-asserts the approach switch meeting conditions [18] progressing to state (9). Alternative, the control means ensures it is safe to perform a bend and observes the material has remained stable while the blade was descending fulfilling condition [15] and progressing to state (9) (the control means may slow the blade to give sufficient time to observe the material).

In state (9) the material is bent until condition [4] is met and the control means returns to state (2).

Bending Side #3

In state (2) the blade retracts until the image of the bent material fills only the lower 20% of the image. The operator, keeping the approach switch asserted, removes the material and rotates it through 90 deg to bend side 3 of the material as per fig 8/3. As the material has been removed from the anvil, the blade approaches the anvil until the anvil fills only the lower 20% of the image area.

The operator, keeping the approach switch asserted, slides the material onto the anvil causing the blade to raise according to the amount the material is lifted as it is placed onto the anvil. In this state, state (2), if the operator raises the material, then the blade is retracted accordingly, however, the blade does not approach the material again as more than the lower 20% of the image fails to match any in the shadow stack.

In order to further describe operation of the control means, we must now assume that for some reason, the operator fully retracts the blade to well above the material and then releases the retract switch causing conditions [2] and [6] to be met, putting the control means into state (3).

The operator asserts the approach switch fulfilling condition [5] and putting the control means into state (2) causing the blade to descend until the material fills the lower 20% of the image area *(as shown in fig 10/1).*

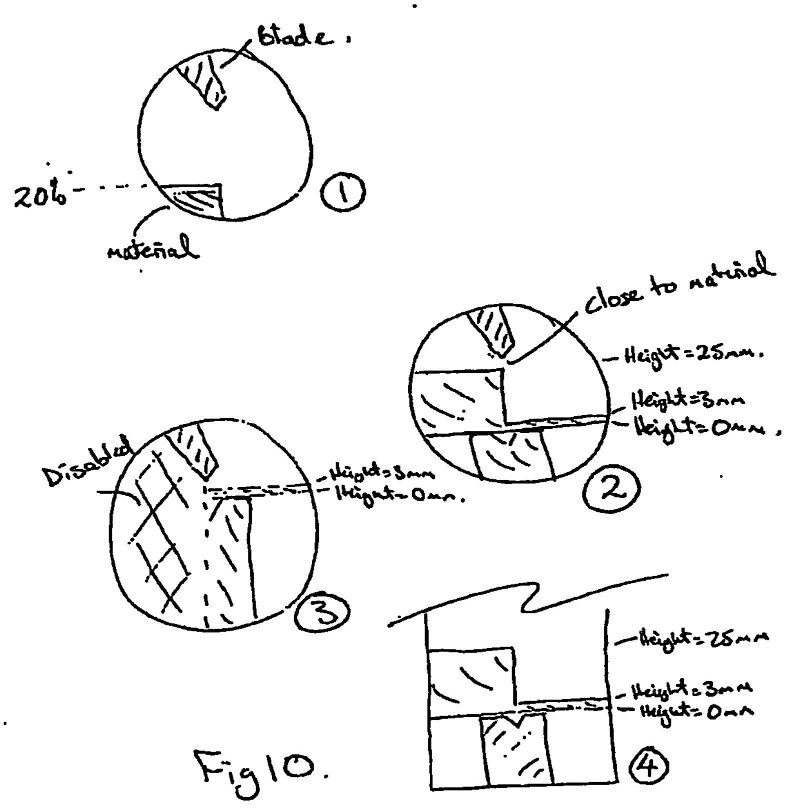


Fig 10.

The operator releases and reasserts the approach switch fulfilling conditions [6] and then [8] so the control means enters state (5). The blade proceeds towards the material until the blade is close to the material *(as shown in fig 10/2)* fulfilling condition [12a] and stopping.

The operator releases and reasserts the approach switch fulfilling conditions [11] and then [8] and entering state (5) after disabling a section of the blade *(as shown in fig 10/3)*. In state (5), the blade proceeds towards the anvil stopping when condition [12c] is met.

The operator releases and reasserts the approach switch fulfilling conditions [14] and entering state (9).

In state (9) the material is bent until condition [4] is met and the control means returns to state (2) after saving the newly created shadow map *(as shown in fig 10/4)* to the shadow stack..

Bending Side #4

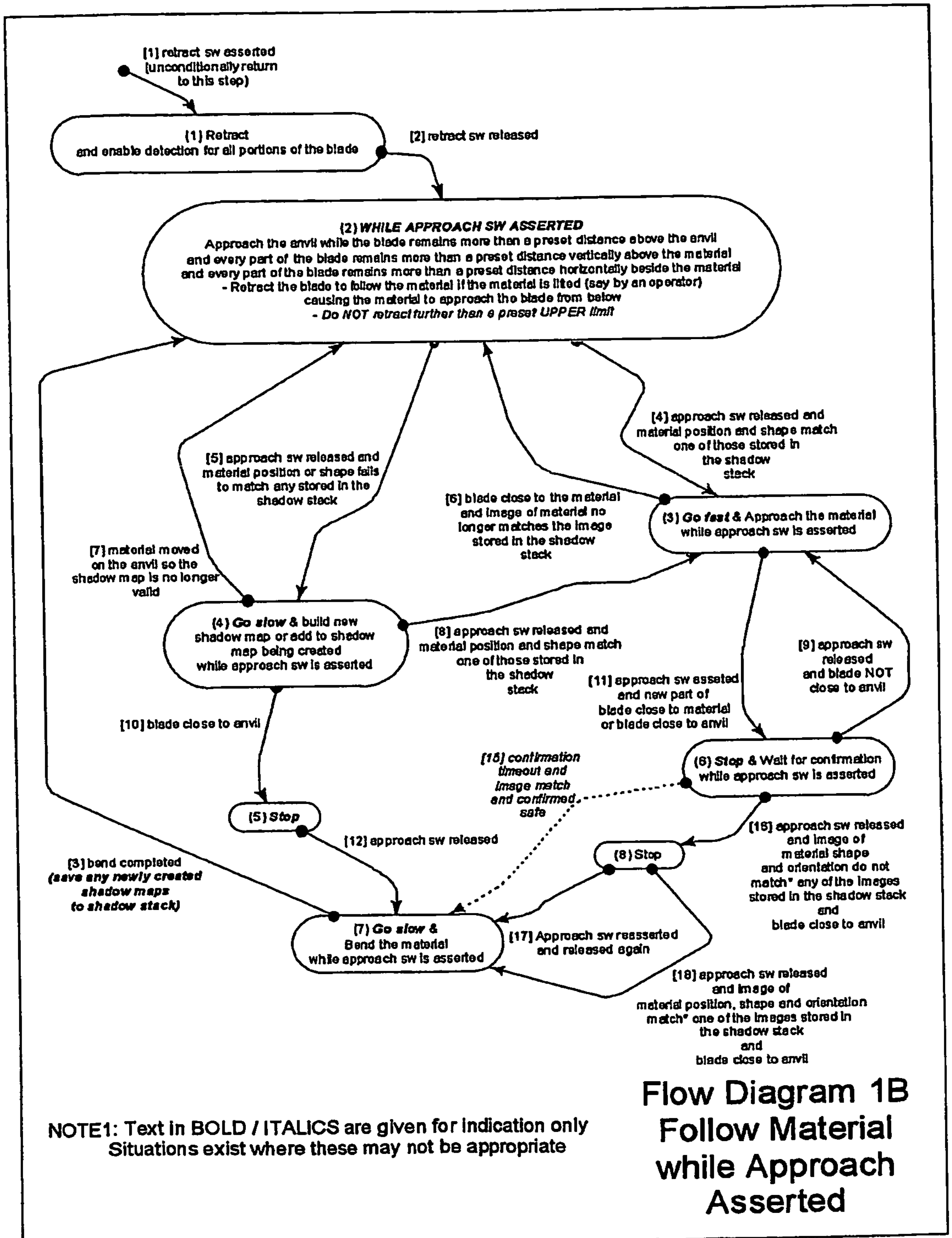
In state (2) the blade retracts until the image of the bent material fills only the lower 20% of the image. The operator, keeping the approach switch asserted, removes the material and rotates it through 180 deg to bend the other side of the material as per fig 8/4.

The blade approaches the material meeting conditions [3] and [13] passing through state (4) to state (6). The blade stops in state (6) so the operator releases and re-asserts the approach switch meeting conditions [18] and progressing to state (9).

In state (9) the material is bent until condition [4] is met and the control means returns to state (2).

Bending a Second Box

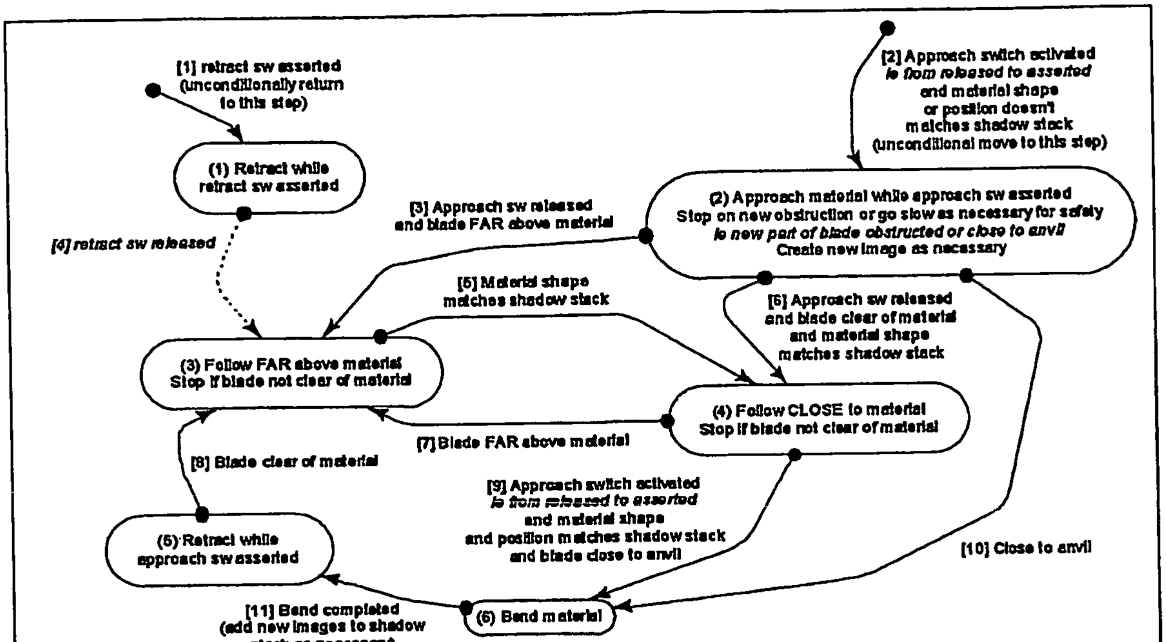
When bending a second box, the operator keeps the approach switch asserted, releasing it 2 times if a mode enabling condition [15] is used or otherwise releasing it 4 times to confirm the bend on each of the four sides.



Flow diagram 1B is similar to 1A with the main difference being that the blade moves at a safe slow speed instead of moving faster and stopping at each new obstruction.

This slow speed is less productive but shows the operator when a new image is being constructed.

Preferred Control Embodiment #2:



Flow Diagram 2 - Auto Approach

An overview of the control means operation for this embodiment is shown in flow diagram 2.

States are numbered in the curved brackets, and conditions required to progress from state to state, shown in the square brackets.

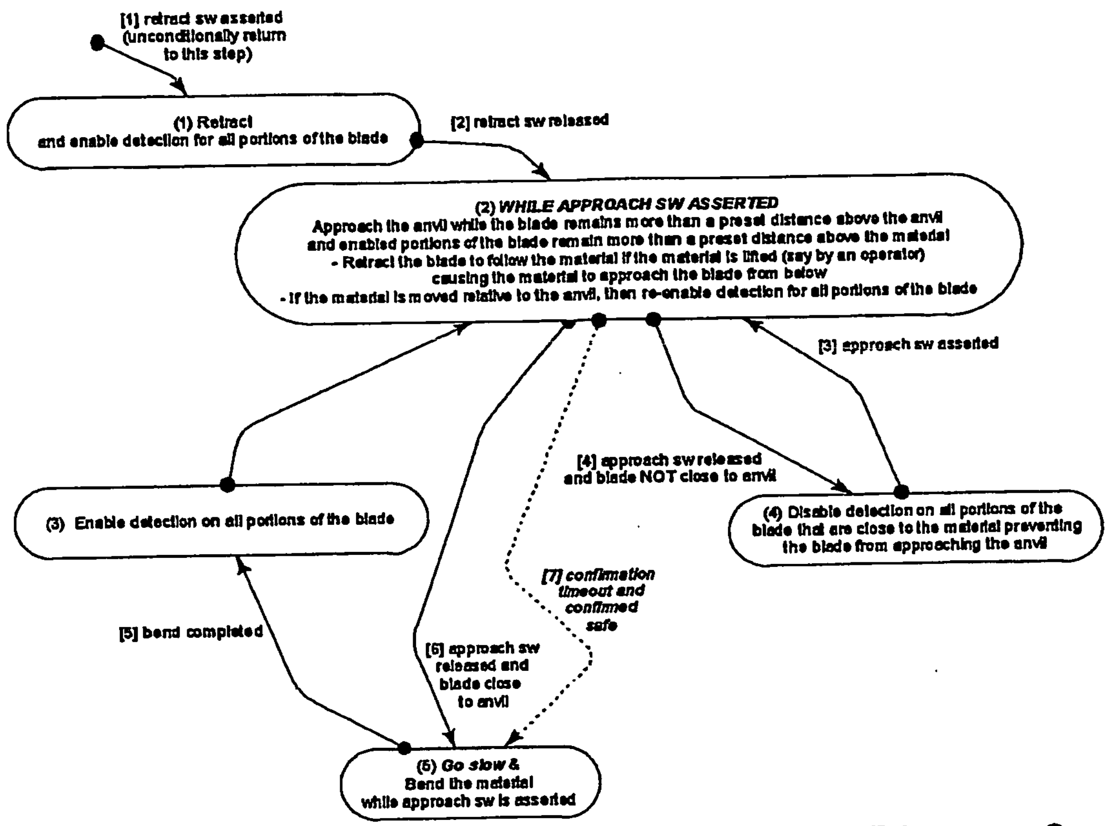
As described above, this embodiment operates similarly to the first, however, the approach switch doesn't have to be held to permit the blade to follow the material. This allows the operator to move around, leaving the approach switch for short periods. Safety is maintained as the blade doesn't move unless either the approach switch is asserted or unless there is no obstruction around the blade.

This embodiment would be useful in situations where it is hard to keep the approach switch asserted while placing and removing material from the anvil.

NOTE: Condition [4] (shown with a dotted line above) is optional.

Preferred Control Embodiment #3:

In a third preferred embodiment, no memory means is used so the operation is simplified accordingly.



NOTE: Text in BOLD / ITALICS are given for indication only
Situations exist where these may not be appropriate

Flow Diagram 3
Follow Material
while Approach
Asserted with
No Shadow Stack

An overview of the control means operation for this embodiment is shown in flow diagram 3. States are numbered in the curved brackets, and conditions required to progress from state to state, shown in the square brackets. Operation is similar to embodiment #1 and can be understood with reference to the description for embodiment #1 as described above.

Other:

For all of these embodiments, to permit the best productivity, the blade speed would be fast where applicable. Blade speed may for instance be guaranteed fast while a zone around the blade is not obstructed, the zone size may be dependent on the stopping performance of the machine and the response time for the control means.

To give increased clearance for removing material, the blade could be raised to a greater height when the material has been bent and until the next piece has been placed on the anvil ready for bending, the control means could determine the material has been bent by examining the top edge of the material, a sloping top edge would indicate bent material whereas a level top edge would indicate the material has been replaced.

The operator could be provided with a second 'follow the material' switch. This would usually be used in place of the retract switch, allowing the bent piece of material to be removed and the new piece inserted ready for bending. The operator would then use the approach switch to perform the final bend.

It is also anticipated that combinations of the embodiments described here and those of PCT/AU03/00707 would be used in order to add flexibility to the system. Further to this, the processing and control means may output a voltage to control the blade movement in a smooth manner, with the speed up or down being smoothly controlled dependent on the state of the system and the positions of the obstructions.

A switch other than the retract or approach switches may be used to control these special modes and these modes may be enabled or disabled by another master control selector.

If the blade approaches and comes close to the material, *(a point where a stop would normally occur)*, then the control means may be programed to permit the blade to travel through the stop point without stopping if it can be seen the situation is safe and the material is already aligned due to a stop occurring just prior to the blade coming close to the material. This would reduce the number of stops occurring and improve productivity.

A mode may be available to the operator where the blade is stopped at programmable point in the cycle until the operator releases and re-asserts the approach switch. This permits the operator to check alignment or check safety.

The control means could be integrated with normal operations of a press break controller so operating modes for the control means or the press bake controller could be dynamically changed, depending on what bends are expected to be performed.

The control means could be pre-programmed with known common material shapes so that operators do not need to setup these shapes every time a similar shape of material is to be bent.

An advanced press brake controller could also 'download' expected material images to the processing and control means and the processing and control means could use this information to ensure the material is positioned correctly for a specified bend.

Alternatively, the processing and control means could 'upload' image information to an advanced controller so the controller could ensure bending is in line with expected parameters.
The press brake controller could also provide information to the processing and control means indicating which step in the bending cycle is being performed and the processing and control means could use this information to determine when the material is positioned incorrectly for the bend being performed.

Also, as described in PCT/AU03/00707 the bending of the material may be analyzed to ensure safety is maintained and the bending of the material is in line with expectations.

Modifications and variations as would be apparent to a skilled addressee are deemed to be within the scope of the present invention.

For example, it is anticipated that at least on of the embodiments could be achieved by using a cylinder lens in front of the light receiving means instead of the lens arrangement described in PCT/AU03/00707. The light receiving means would have (say 10) individual light sensors placed side by side at the focal length of the lens. These sensors would output an analogue voltage (potentially multiplexed and/or digitized using an ADC) that represents the amount of light falling on them. A light emitting means similar to that described in PCT/AU03/00707 could be masked so a band of light (say 15mm high) is emitted.

This produces a light receiving means that has analogue outputs in which each analogue voltage represents the vertical portion of light that is obstructed between the light emitting and light receiving means.

The processing and control means would use this information to calculate the approximate vertical distance between the top of the light band (or the blade if the beam is partially obstructed by the blade) and the material (that has been placed onto the anvil). Operation of the preferred embodiment would be altered to accommodate this style of light receiving means.

Document made available under the Patent Cooperation Treaty (PCT)

International application number: PCT/AU04/001739

International filing date: 10 December 2004 (10.12.2004)

Document type: Certified copy of priority document

Document details: Country/Office: AU
Number: 2004903144
Filing date: 11 June 2004 (11.06.2004)

Date of receipt at the International Bureau: 04 January 2005 (04.01.2005)

Remark: Priority document submitted or transmitted to the International Bureau in compliance with Rule 17.1(a) or (b)

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